D-meson and hadron correlations in the ALICE experiment and in simulations

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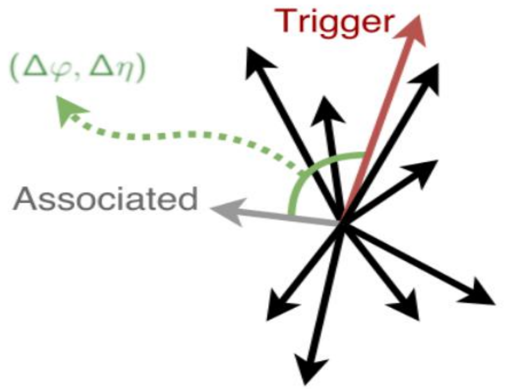
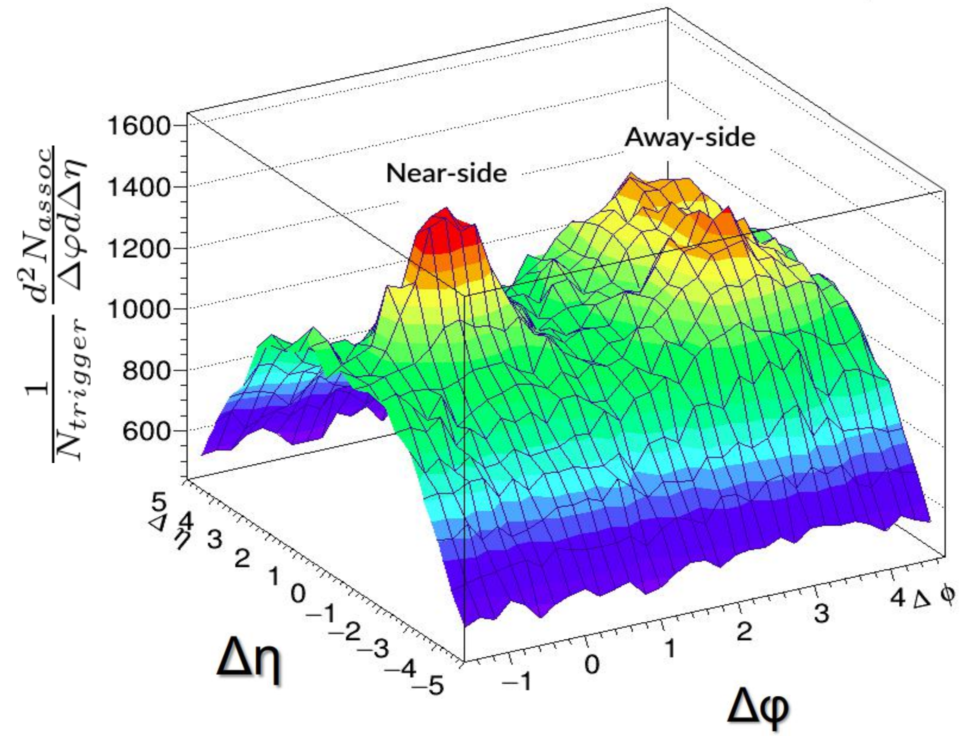
ALICE

MŰEGYETEM 1782

Physics motivation

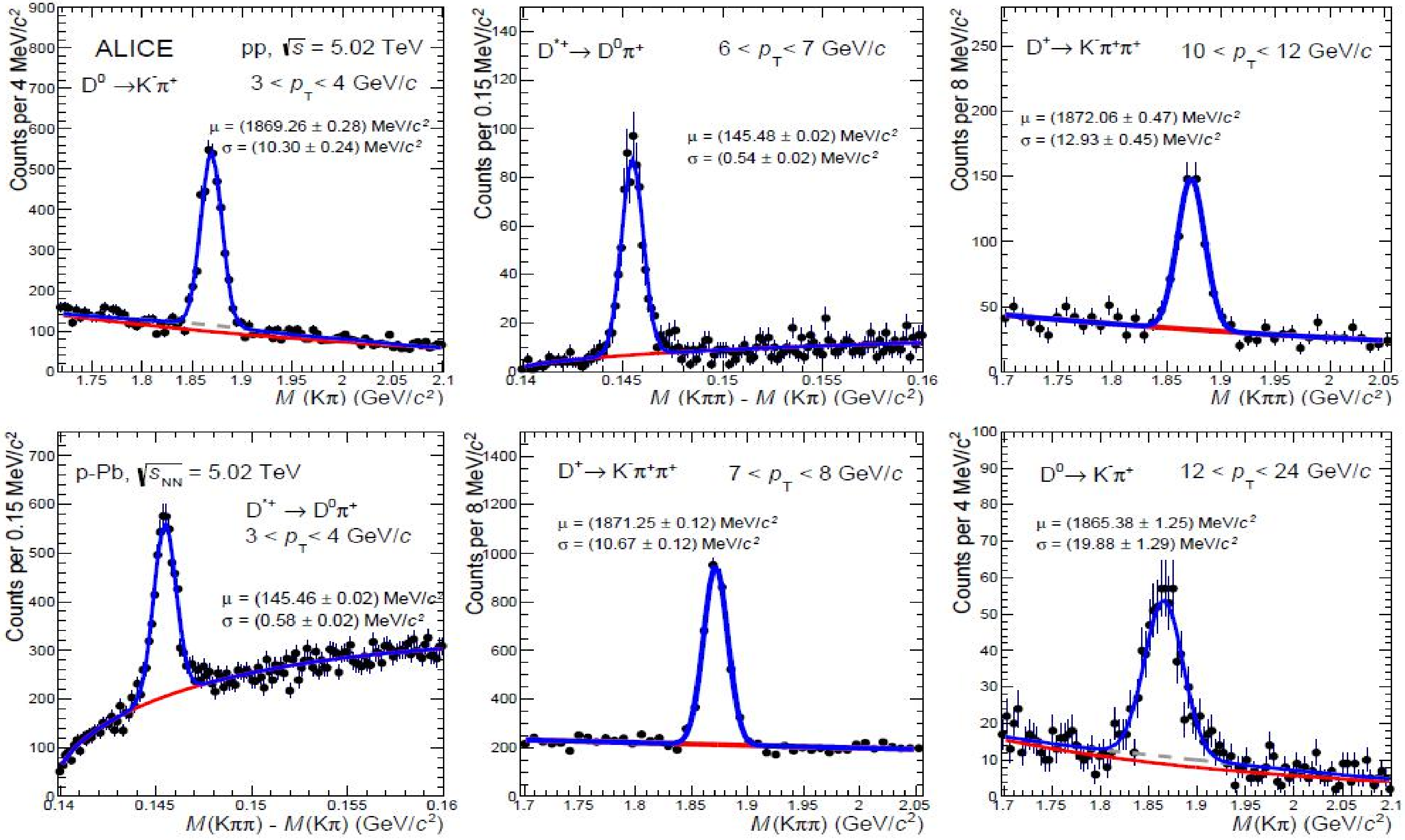
- In both soft and hard processes, the direction of the produced particles are correlated
- Associated charged particles with D mesons as the trigger
  - sensitive to the charm-quark production, fragmentation, and hadronisation processes in proton-proton collisions
- Pseudorapidity(η) and azimuth angle(φ)
- Calculating the Δη and Δφ differences
- Associated yield per trigger $\frac{1}{N_{\mathrm{trigger}}}\frac{\mathrm{d}^2 N_{\mathrm{assoc.}}}{\mathrm{d}\Delta\varphi\mathrm{d}\Delta\eta}$





Reconstruction of D mesons in ALICE

- pp and p-Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV
- charged hadron tracks reconstructed in the ITS and TPC
- topological reconstruction of secondary vertexes
- D-meson raw yields extracted from invariant mass fits in several p_T intervals



D-meson reconstruction:

- $D^+ \rightarrow K^- \pi^+ \pi^+$ BR~ 9.5%
- $D^{*+} \rightarrow D^0 \pi^+ \rightarrow K^- \pi^+ \pi^+$ BR ~ 2.6%
- $D^0 \rightarrow K^- \pi^+$ BR ~ 3.9%

arXiv:1910.14403

Evaluation and correction of the azimuthal-correlation functions

- D-meson candidates are selected from the +/- 2σ peak region
- Correlation distribution C(Δφ,Δη) evaluated in several p_T^D and p_T^{assoc} intervals
- Acceptance corrections based on mixed event technique, and reconstruction efficiency corrections are applied for both the trigger and associated particles
- The combinatorial background, properly normalized from the sideband, is subtracted from the peak-region correlation:

$$\tilde{C}_{\text{inclusive}}(\Delta\varphi,\Delta\eta) = \frac{p_{\text{prim}}(\Delta\varphi)}{S_{\text{peak}}}\left(\left.\frac{C(\Delta\varphi,\Delta\eta)}{\text{ME}(\Delta\varphi,\Delta\eta)}\right|_{\text{peak}} - \frac{B_{\text{peak}}}{B_{\text{sidebands}}}\left.\frac{C(\Delta\varphi,\Delta\eta)}{\text{ME}(\Delta\varphi,\Delta\eta)}\right|_{\text{sidebands}}\right)$$

- Feed-down D-meson contributions from beauty decays:
  - can influence the shape of the correlations (Universe 2019 5 (5), 118)
  - Generator-level Monte Carlo simulations are used to substract non-prompt D-contribution

D-h correlation peak fits

Average of D^0, D^+, D^{*+} contributions
The fit function:

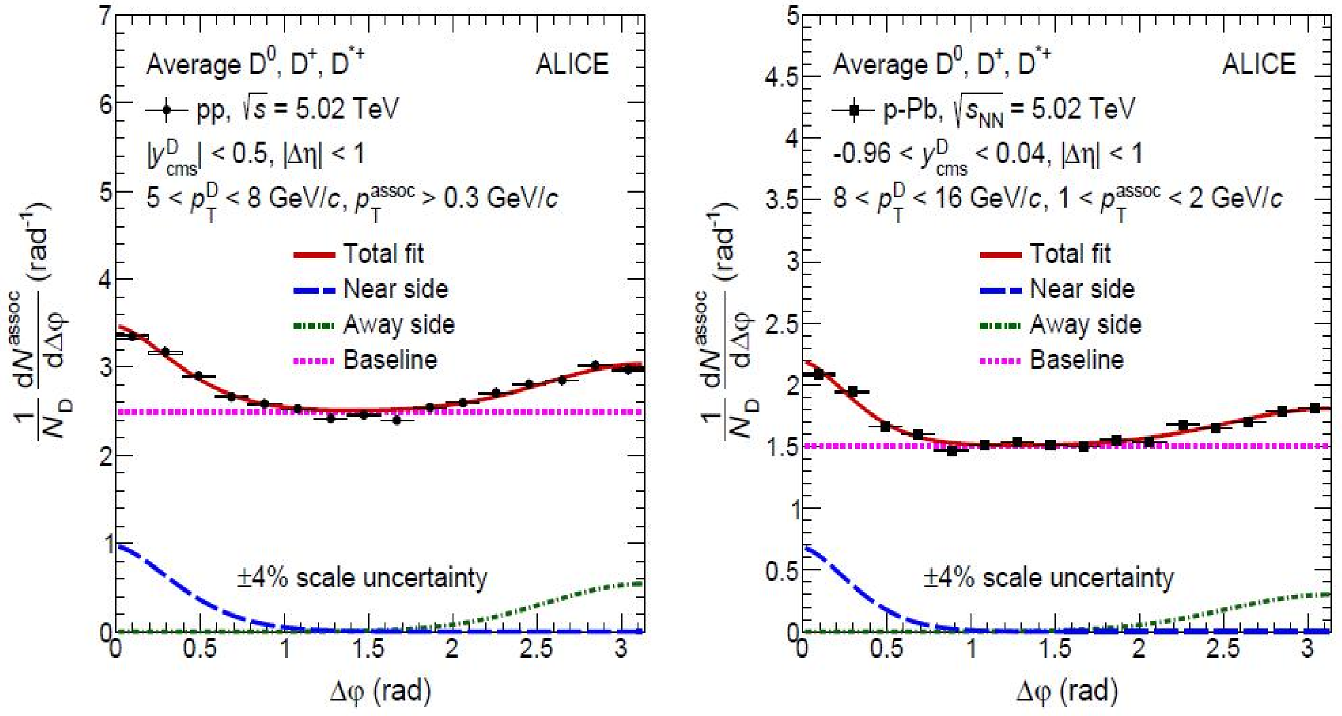
- a constant term b describing the flat contribution below the correlation peaks,
- a generalised Gaussian term describing the near-side peak,
- a Gaussian reproducing the away-side peak.

α : is related to the variance of the function, hence to its width
β : drives the shape of the peak (the Gaussian function is obtained for β = 2)

$$f(\Delta\varphi) = b + \frac{Y_{NS}\cdot\beta}{2\alpha\Gamma(1/\beta)}\cdot e^{-\left(\frac{\Delta\varphi}{\alpha}\right)^{\beta}} + \frac{Y_{AS}}{\sqrt{2\pi}\sigma_{AS}}\cdot e^{\frac{(\Delta\varphi-\pi)^2}{2\sigma_{AS}^2}}$$

near-side widths of the correlation peaks are described by the square root of the variance:

$$\alpha\sqrt{\Gamma(3/\beta)/\Gamma(1/\beta)}$$



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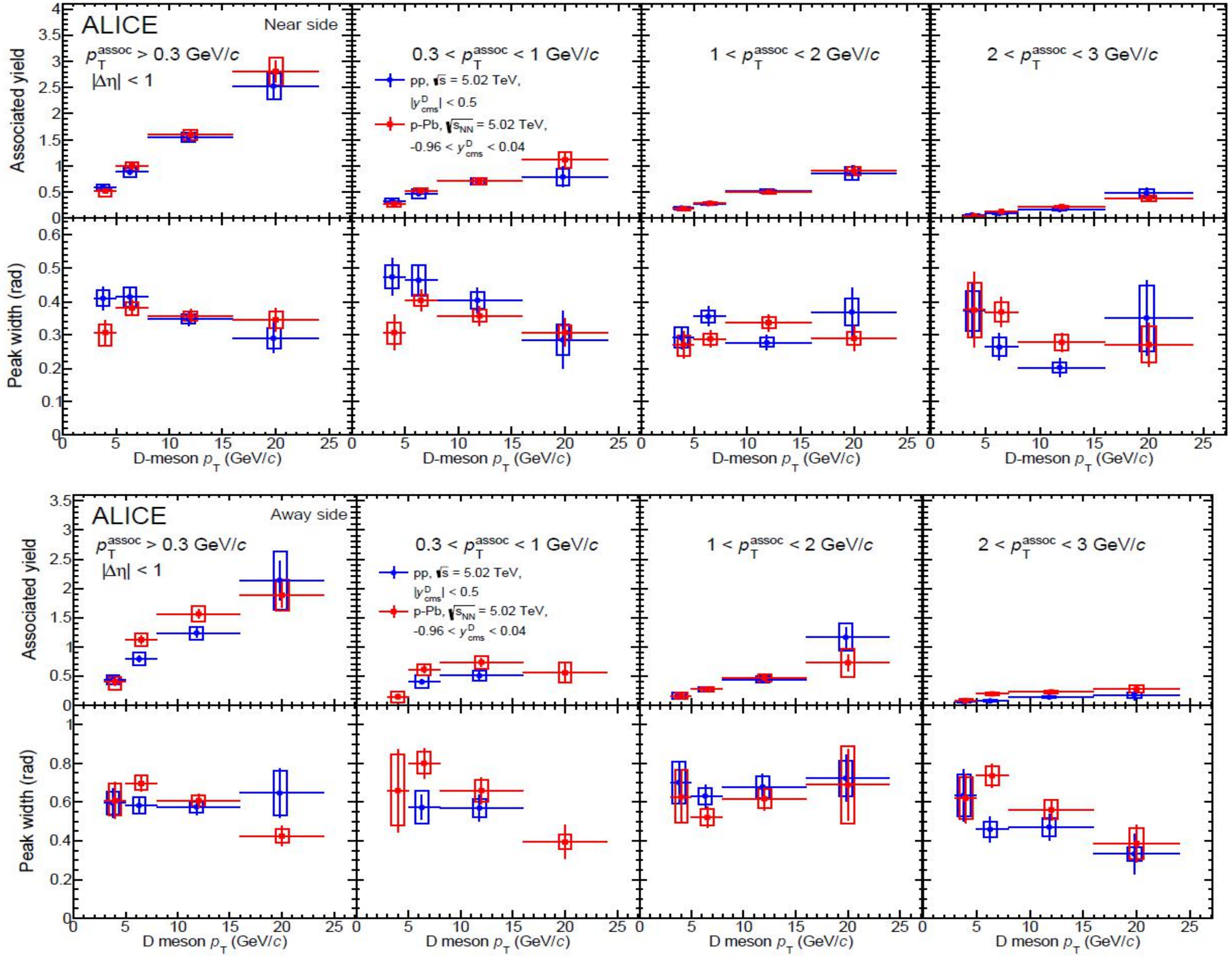
Comparison of results in pp and p–Pb collisions



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Near-side peak

- A tendency for a narrowing of the near-side peak with increasing p_T^D, signalled by a decrease of the peak width.

Away-side peak

- The away-side yields show an increasing trend with p_T^D values in the two collision systems.
- The away-side peak widths show compatible values in pp and p–Pb collisions in all kinematic ranges.

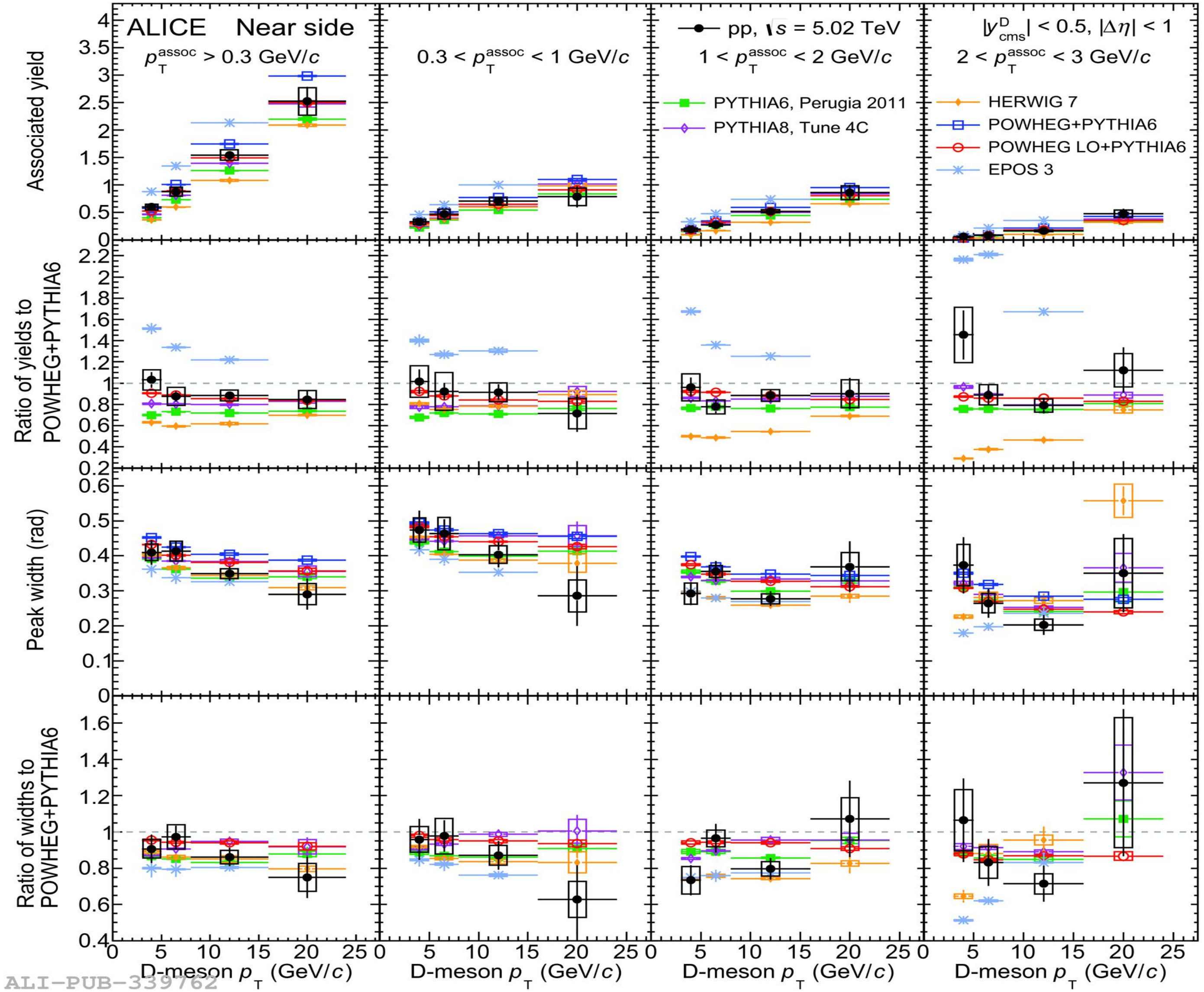
No significant impact from cold-nuclear-matter effects on the fragmentation of charm quarks within the current precision.

Comparsion to Monte Carlo simulations (near-side)

PYTHIA6: LO generator with initial and final state parton shower, Lund string fragmentation.
PYTHIA8: also includes multiple-parton interactions and improved colour reconnection description.
HERWIG 7: NLO including heavy flavor, cluster hadronisation model, the showering ordering is different from PYTHIA (angular ordering with respect to p_T ordering).
POWHEG+PYTHIA: NLO calculation of hard processes, followed by Lund fragmentation.
POWHEG LO+PYTHIA: hard process stopped at the LO level, Lund fragmentation.
EPOS3: 3D+1 viscous hydrodynamical evolution starting from flux tube initial conditions, which are generated in the Gribov-Regge multiple scattering framework.

Near-side and away-side: sensitivity to fragmentation and parton shower

- Best description by POWHEG+PYTHIA6, POWHEG LO +PYTHIA6 and PYTHIA8 & Yields typically underestimated by HERWIG & NLO models predict slightly broader peaks & EPOS3 typically overpredicts the yields



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Comparsion to Monte Carlo simulations (away-side)

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HERWIG 7: NLO including heavy flavor, cluster hadronisation model, the showering ordering is different from PYTHIA (angular ordering with respect to p_T ordering).
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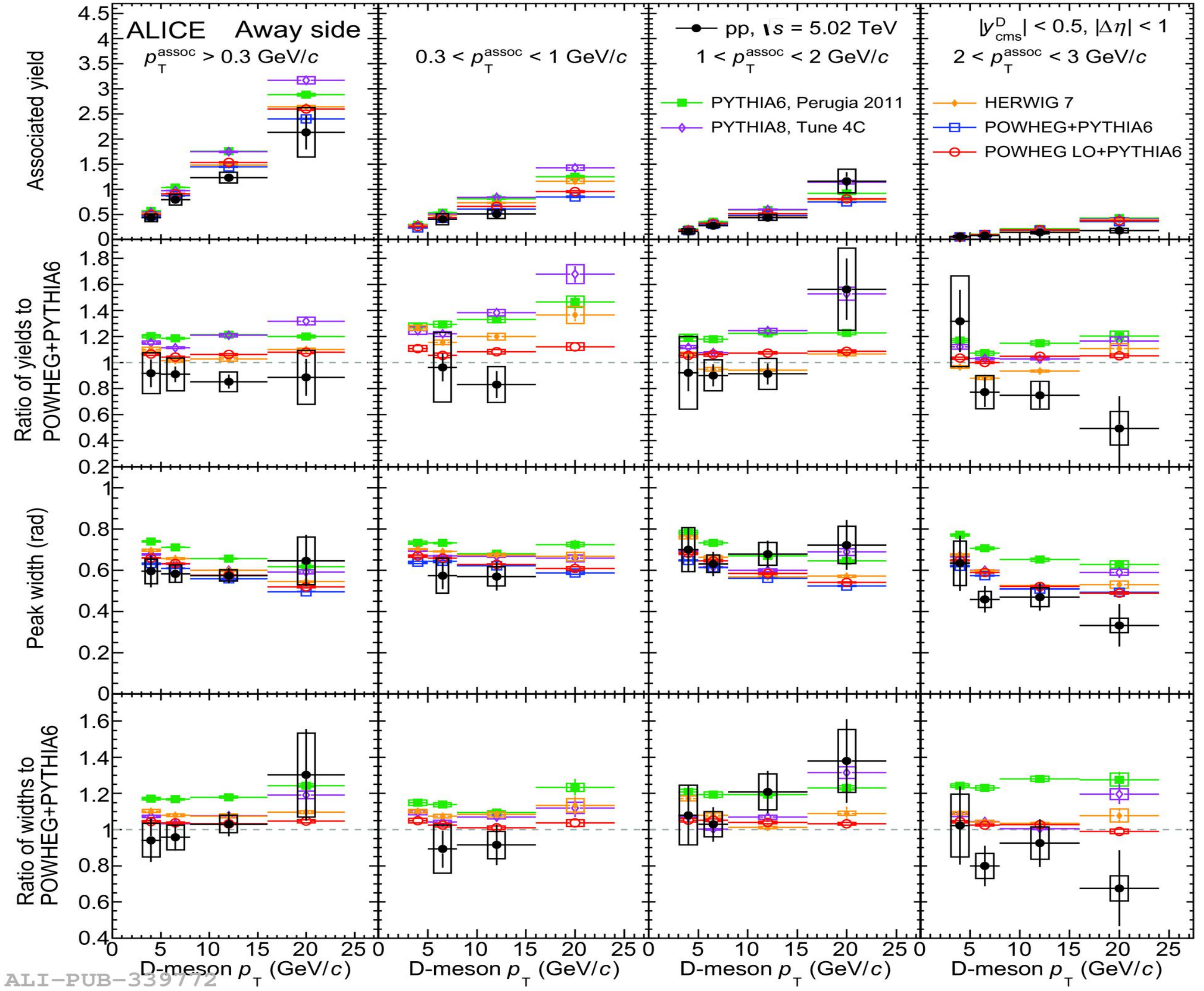
- PYTHIA6 (Perugia11) overpredicts both the yields and widths & PYTHIA8 (4C) overpredicts low-p_T yields and widths



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Comparsion to Monte Carlo simulations (baseline)

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Near-side and away-side: sensitivity to fragmentation and parton shower

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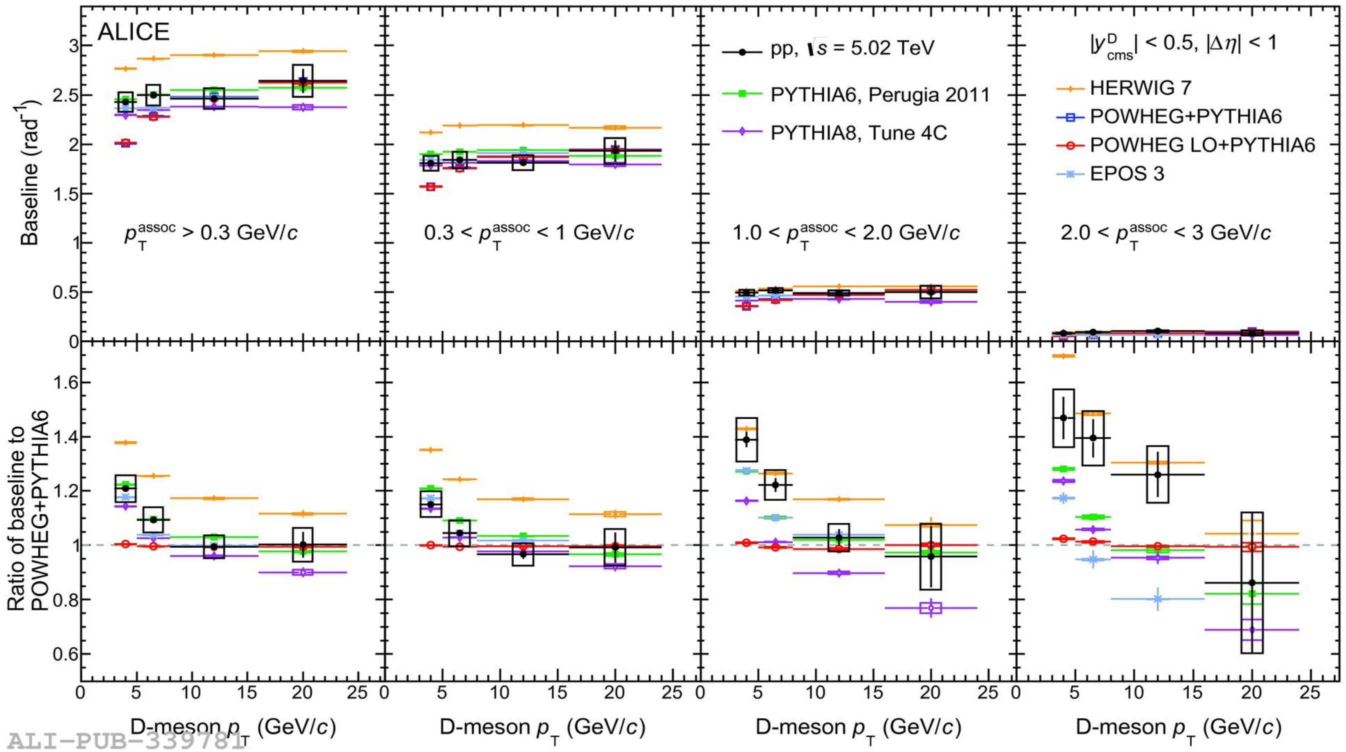

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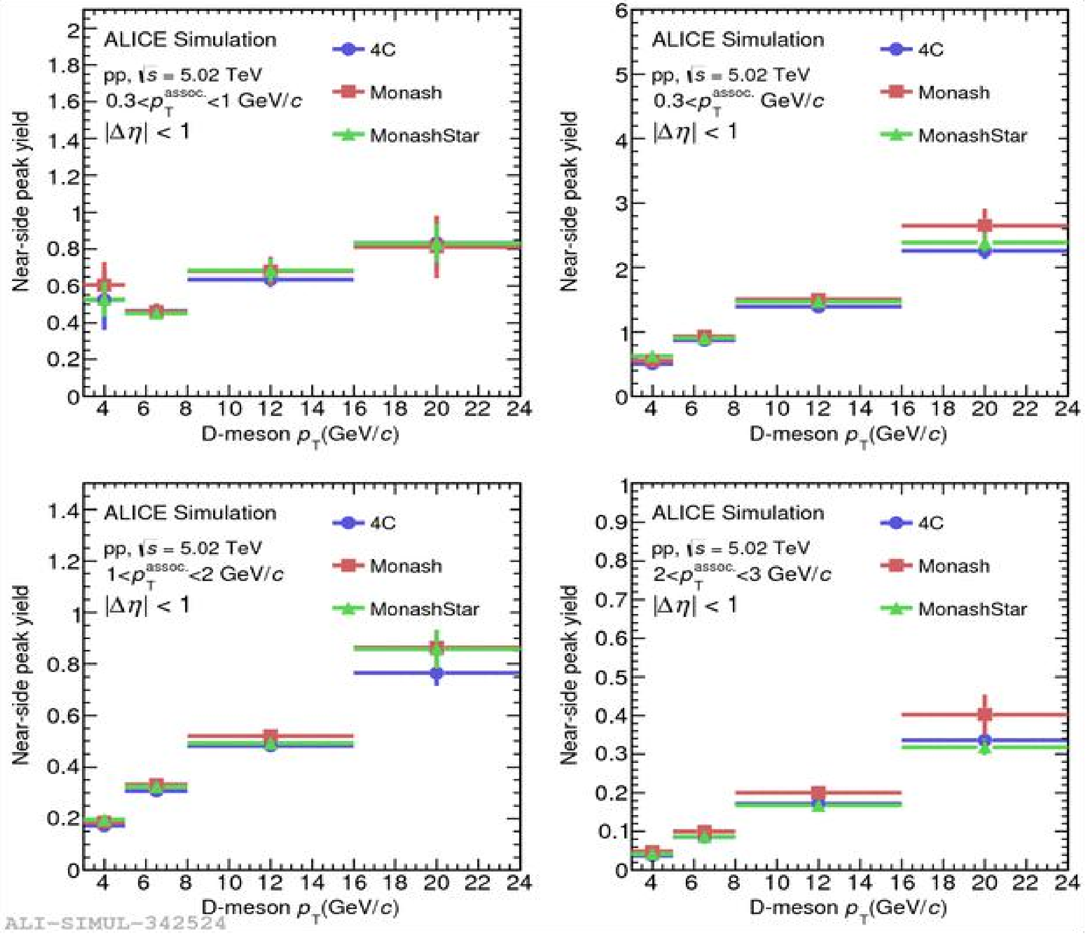
Baseline: Sensitive to the underlying event

- p_T^{assoc}<1 GeV: best description by PYTHIA
- p_T^{assoc}>1 GeV: best description by HERWIG
- POWHEG NLO and LO are the same in all ranges (not trivial since influence expected from NLO charm contributions)

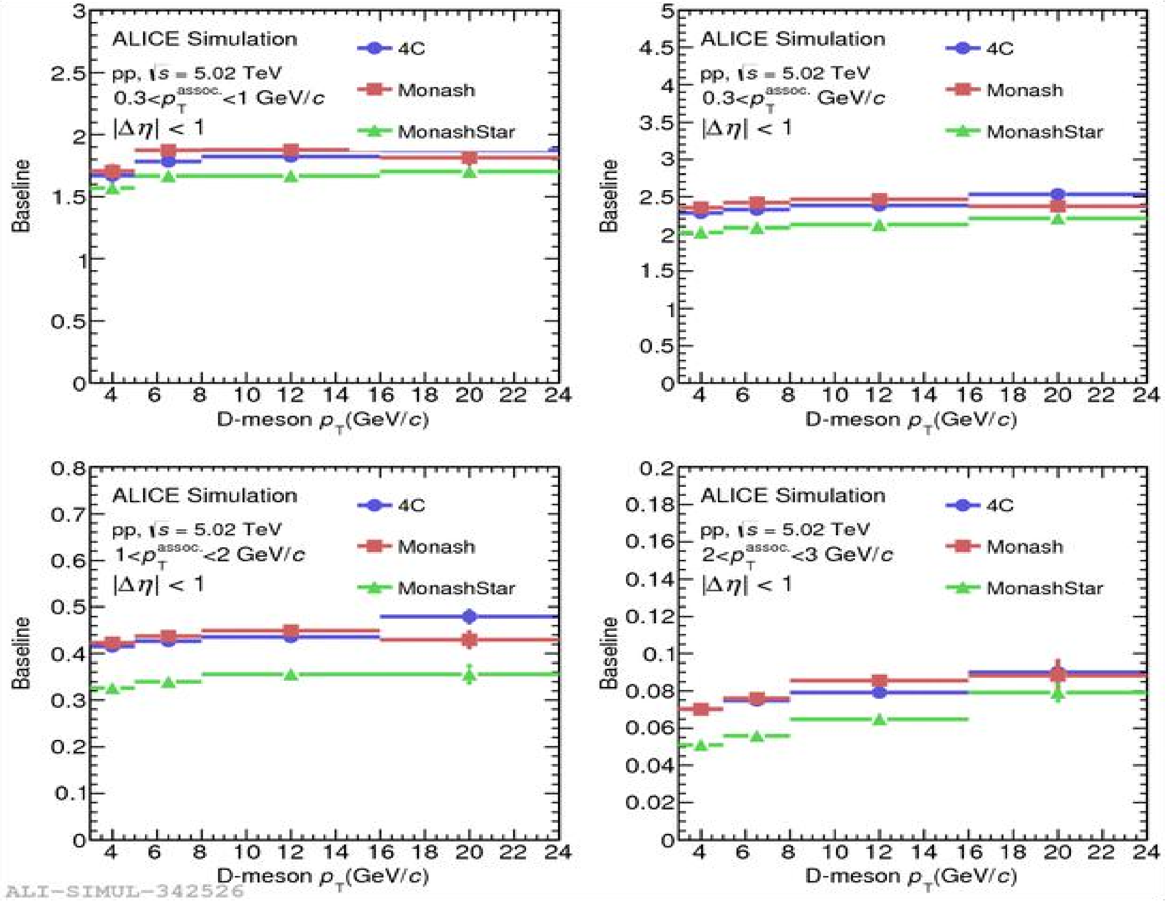
INVESTIGATION OF CORRELATIONS USING PYTHIA 8

Different tunes

Near-side peak yield



Baseline



- Near side peaks are similarly predicted
- Significantly lower baseline for MonashStar (~20% at max)
- Different underlying events

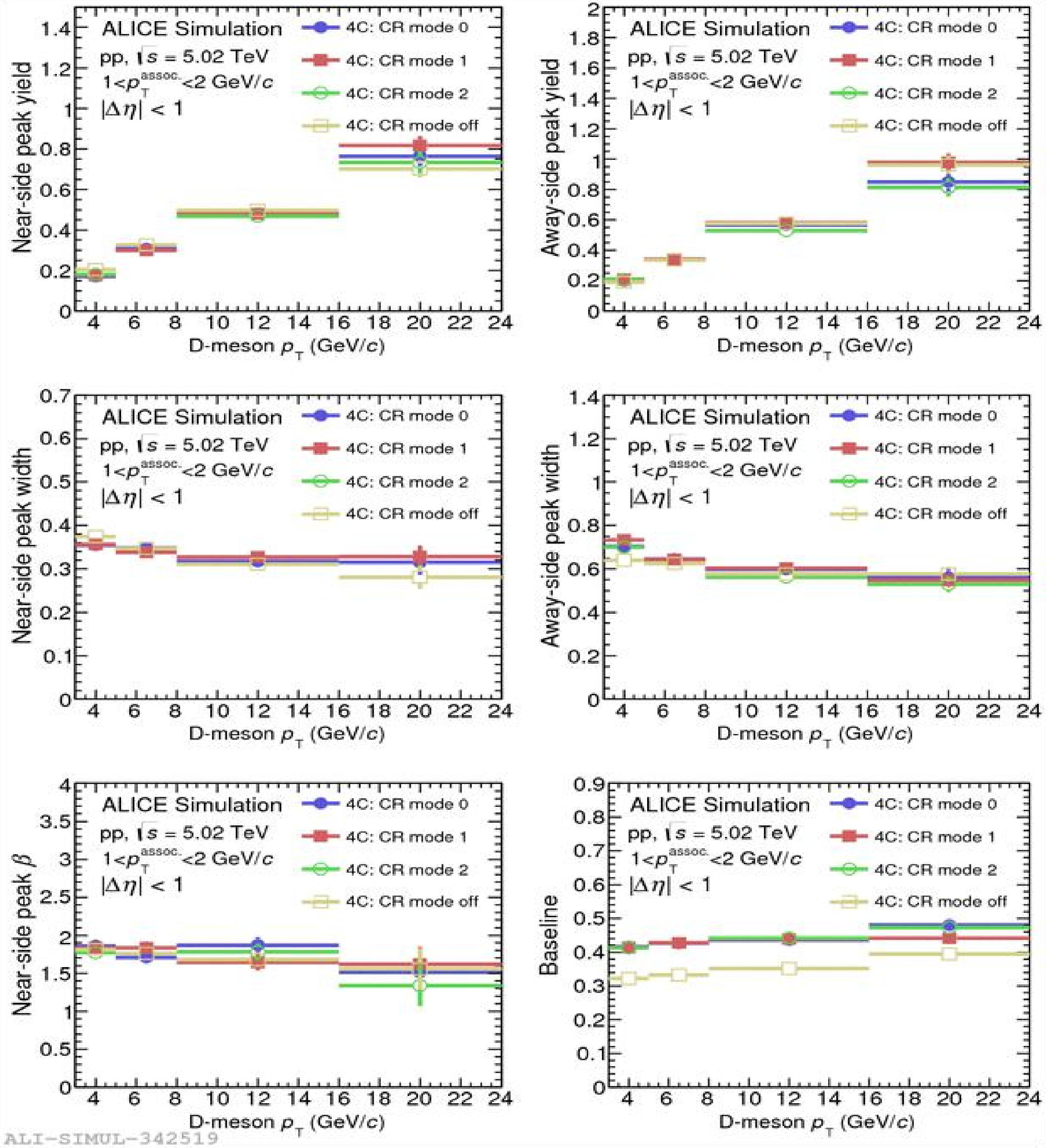
Different colour reconnection modes

- Mode 0 : The MPI-based original Pythia 8 scheme.
- Mode 1 : The new QCD based scheme.
- Mode 2 : The new gluon-move model.
- Reconnection off.

A tendency for a narrowing of the near-side and away-side peak with increasing p_T^D.

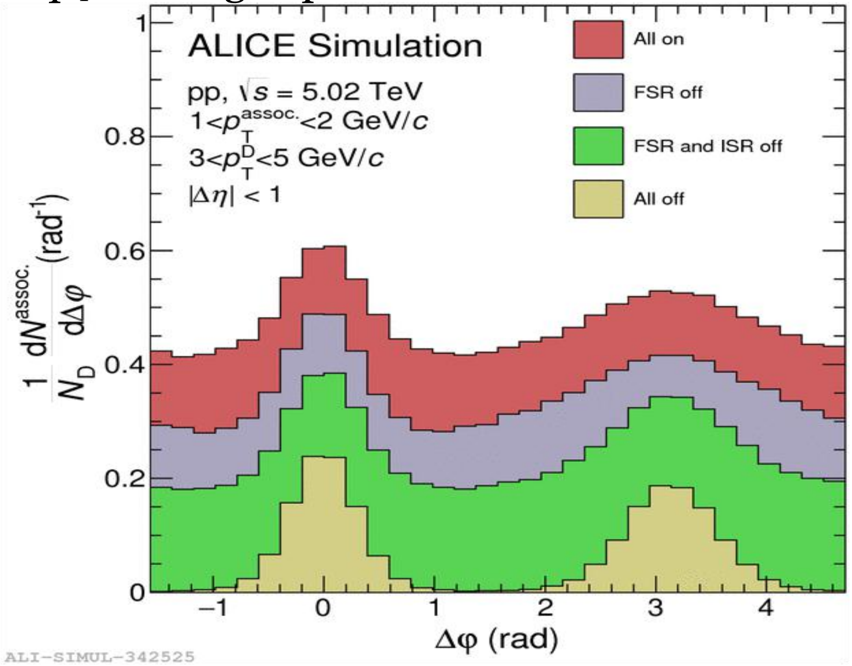
An increasing trend of the near-side and away-side yield with increasing p_T^D.

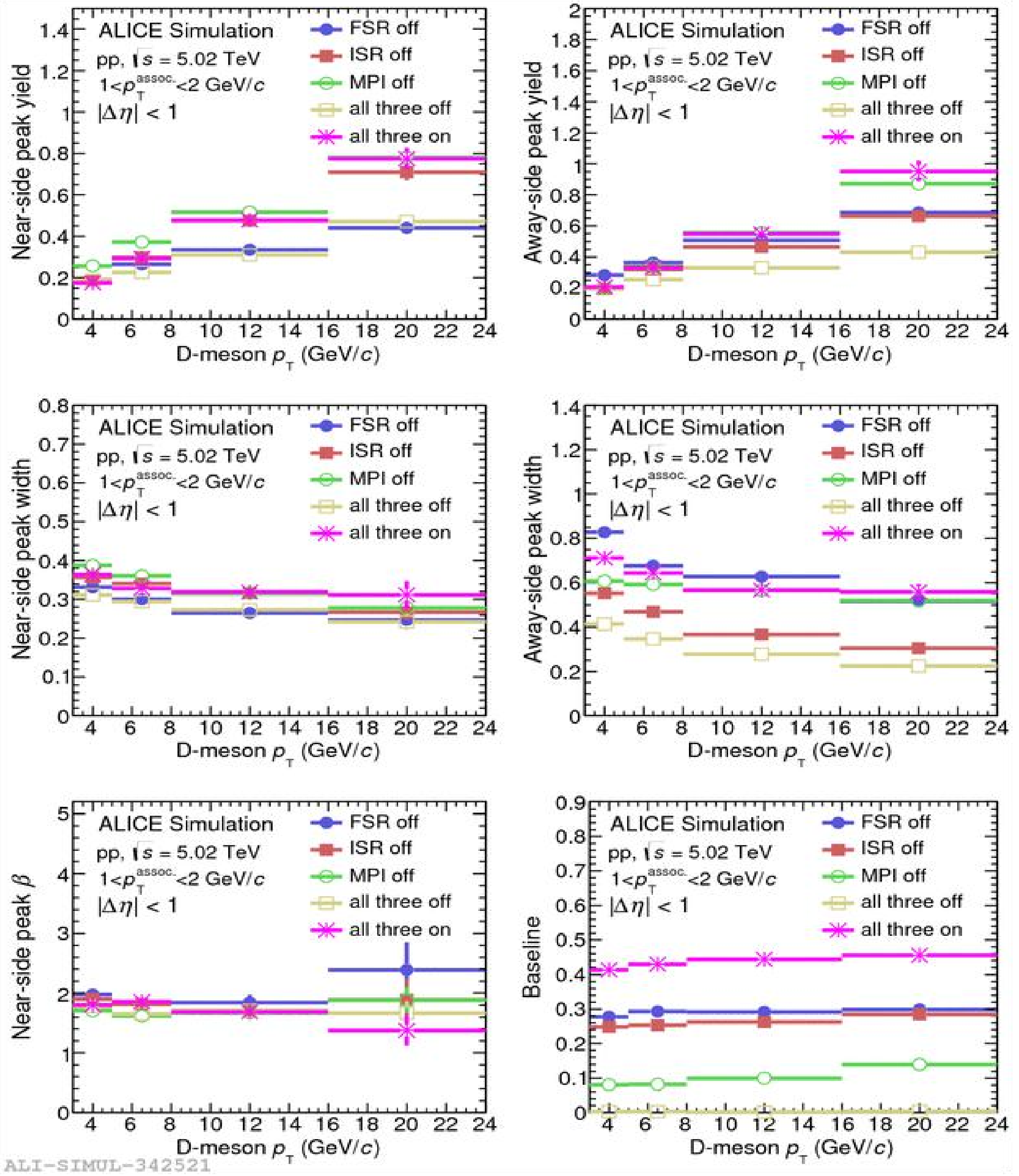
Baseline: Other parameters than CR off are mostly the same => difference only in underlying event.



Different parton level contributions

Near-side yield: significant contribution of FSR at higher trigger $p_T^{trigger}$.
Near-side width and shape: no change, maybe it is driven by fragmentation/hadronic state.
Away-side yield: Significant contribution from MPI.
Away-side width: Contributions of parton-level effects make it wider as expected (especially ISR). FSR=off overshoots all=ON.
Baseline: Contributions of parton-level effects to underlying event as expected. Weak p_T-leading dependence.



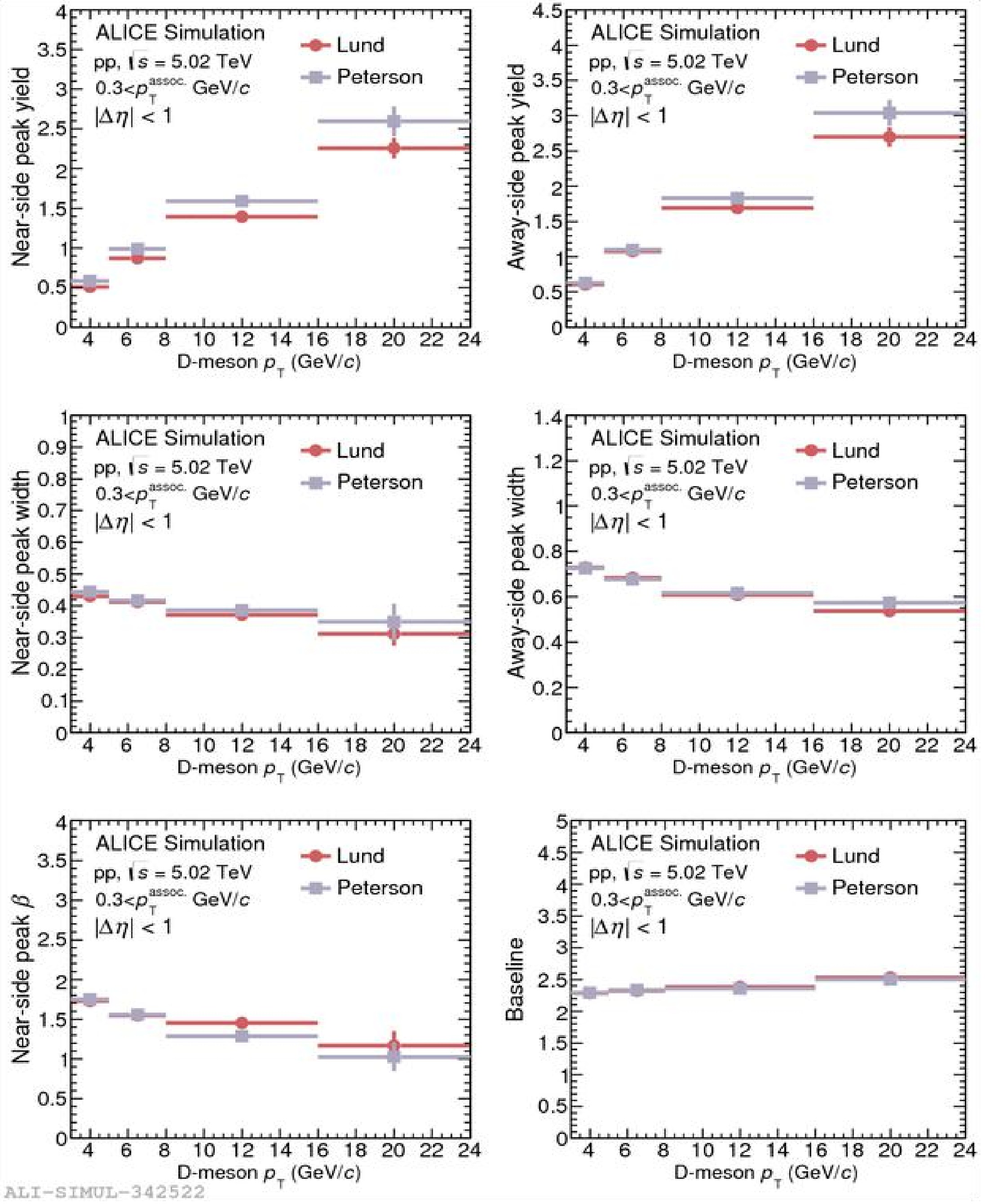


Heavy-flavour fragmentation (Lund vs. Peterson model)

Peterson formula is a fragmentation function for heavy quarks. We use this instead of the Lund formula. For fits to experimental data, better agreement can be obtained.

$$f(z) = \frac{1}{z(1 - \frac{1}{z} - \frac{\epsilon}{1-z})^2}$$

Hint of different trends, but
no significant difference between the two model.

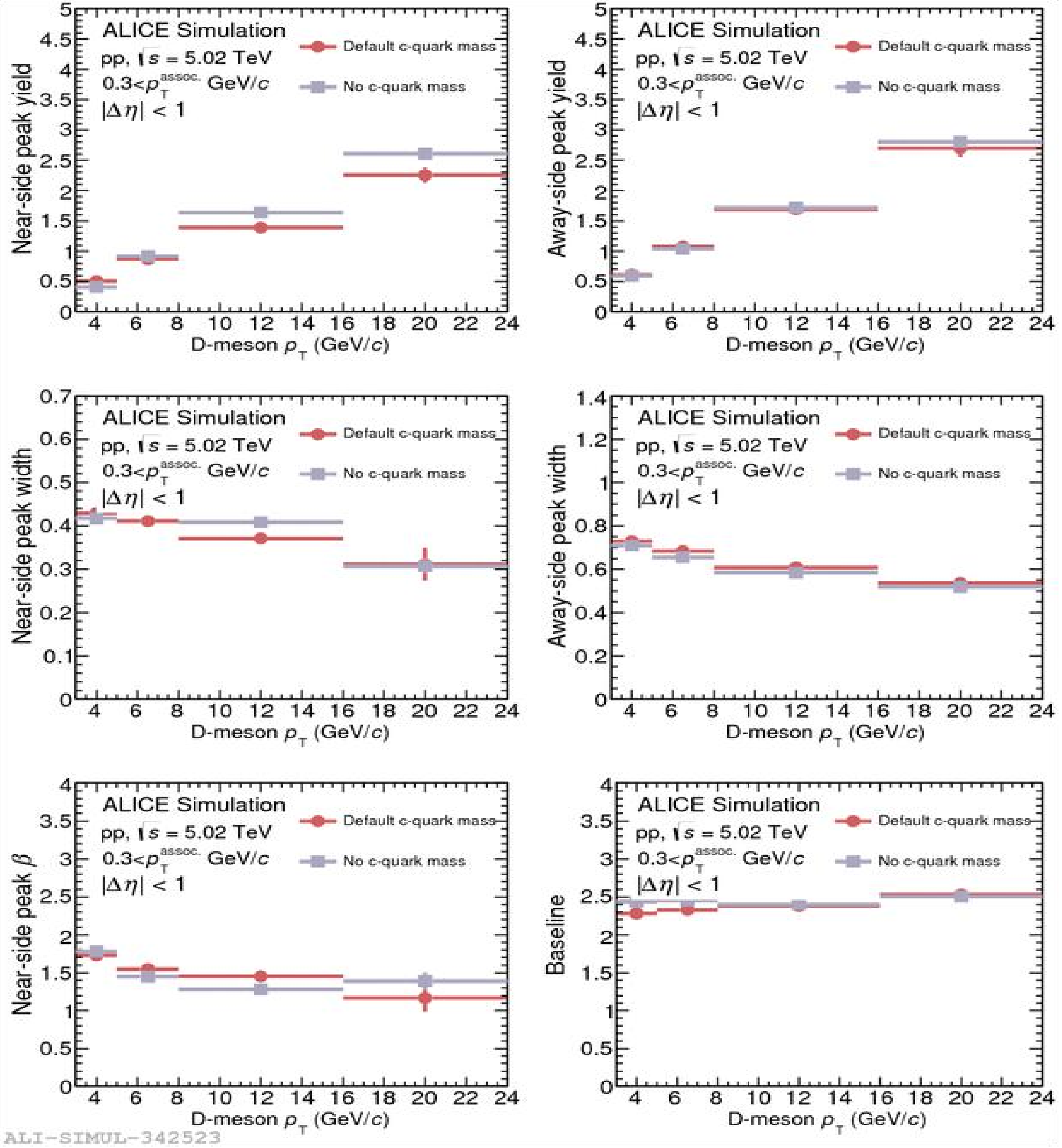


No c-quark mass

Disable the charm quark mass in order to sort the mass cone effect and the color charge effect.

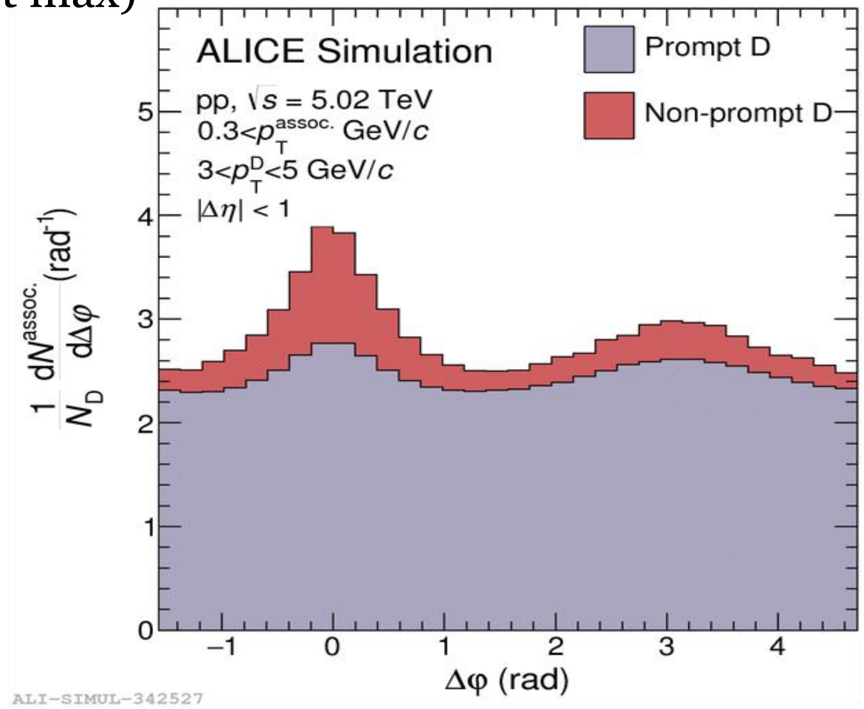
Slight differences at near-side width and yield.

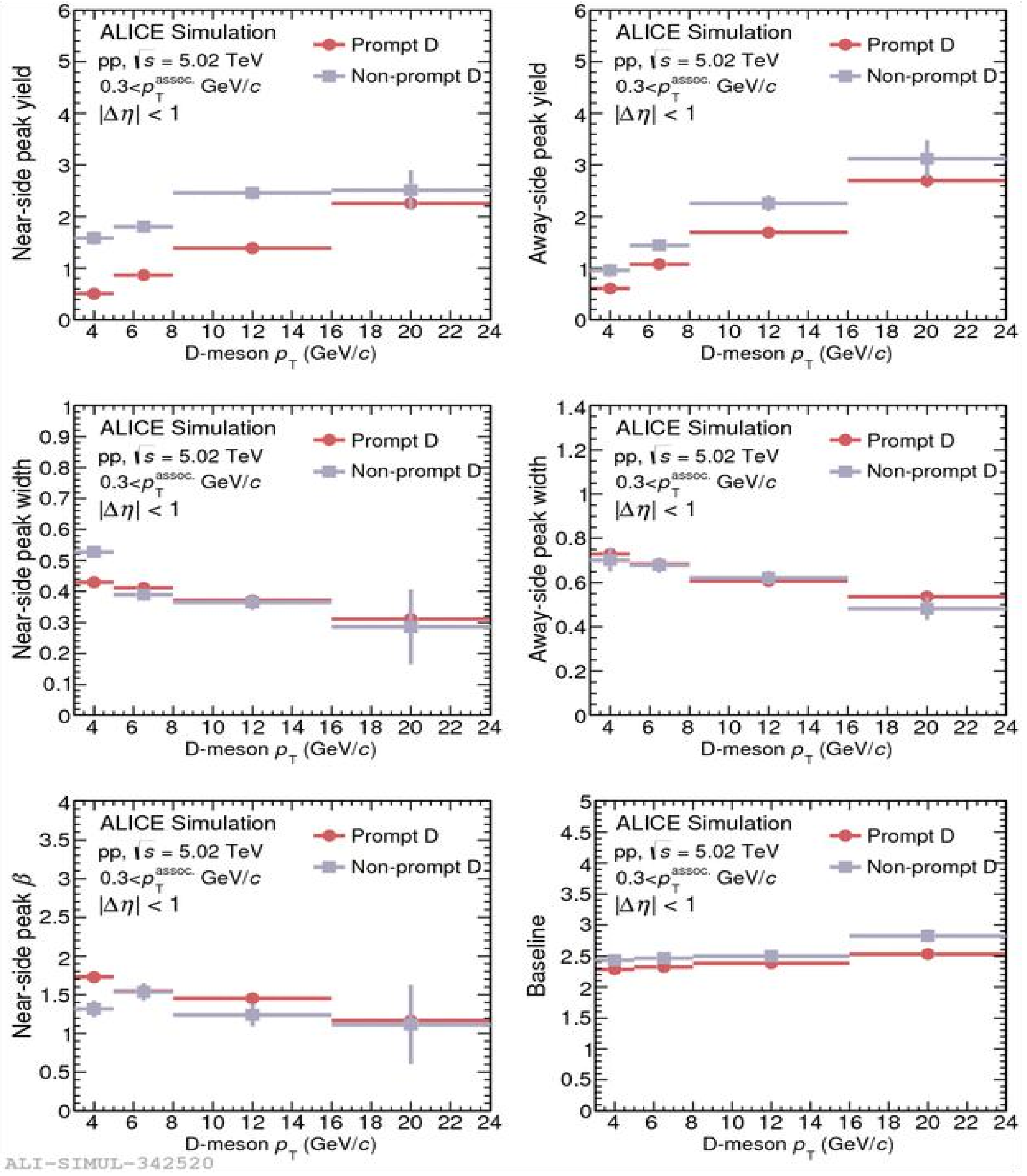
Baseline: Slight difference in underlying event at low p_{T}.



Prompt and non-prompt D-meson separation

Near-side yield and away-side yield: non-prompt D meson is significantly higher. (~50% max)
Near-side and away-side width and shape: significantly different near-side shape at low p_T.
Baseline:Significantly higher baseline for non-prompt D meson (~10% at max)





Summary

ALICE measurements of azimuthal-correlation distributions of D^0, D^{*+}, and D^+ mesons with charged particles in pp and p–Pb collisions at 5.02 TeV

- No strong dependence on system (pp vs. pPb): the fragmentation and hadronisation of charm quarks is **not strongly influenced by cold-nuclear-matter effects.**
- Best description by POWHEG+PYTHIA: importance of NLO processes in correlations.
- HERWIG underestimates near-side yields and baseline at low p_T: shortcomings of cluster fragmentation model.

Investigation of correlations using simulation components

- *Different PYTHIA tunes*: importance of underlying event contribution to background.
- Important role of *colour reconnection*, but no significant difference between colour reconnection models.
- Contribution of *parton-level effects* (ISR,FSR and MPI) to underlying event and away-side peak.
- No significant difference depending on *Lund vs. Peterson fragmentation model*.
- Slight differences when setting the *c-quark mass to 0*: role of dead cone effect in fragmentation.
- Correlations: a tool to statistically separate *prompt and non-prompt contributions*.

Thanks for your attention!

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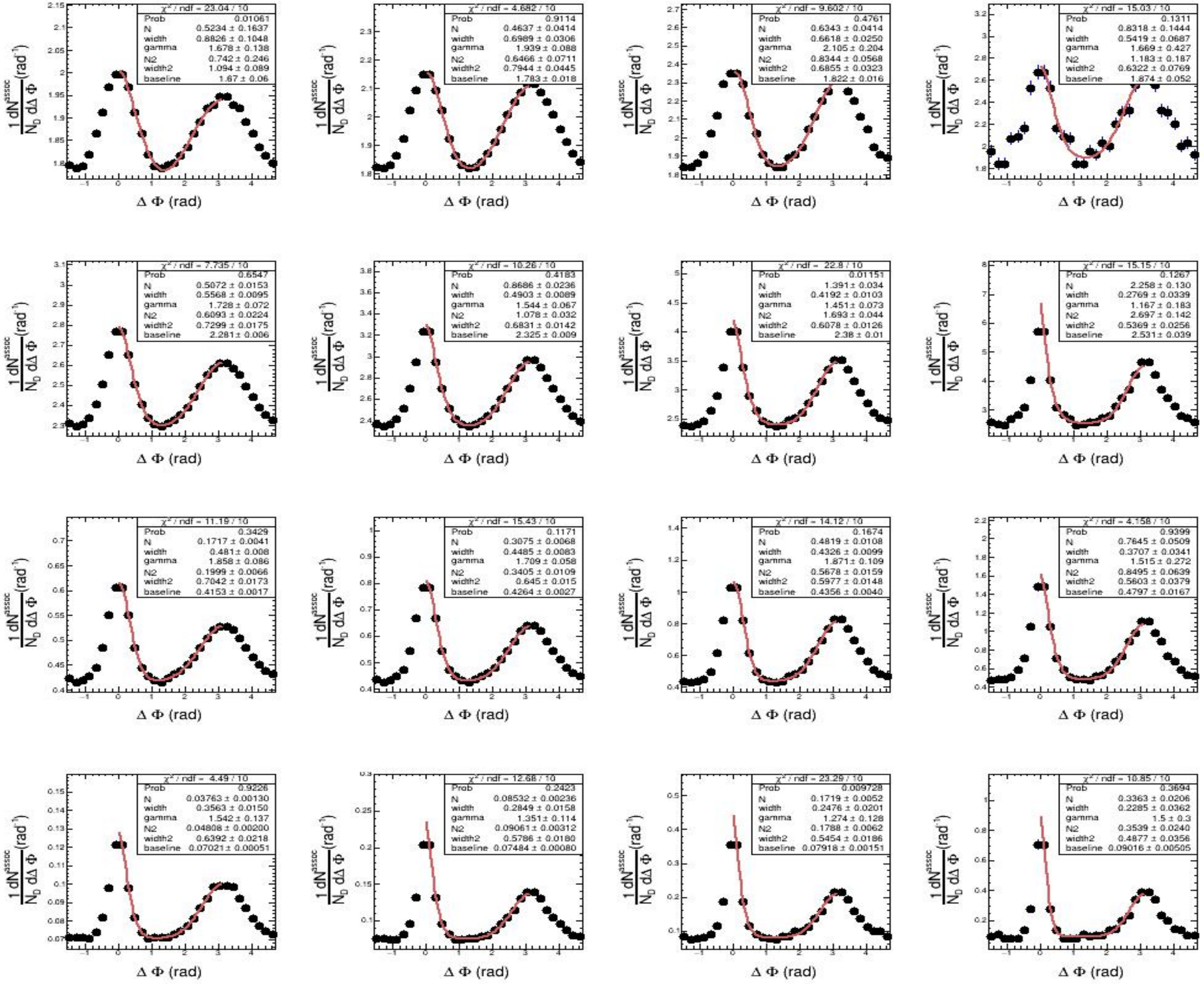
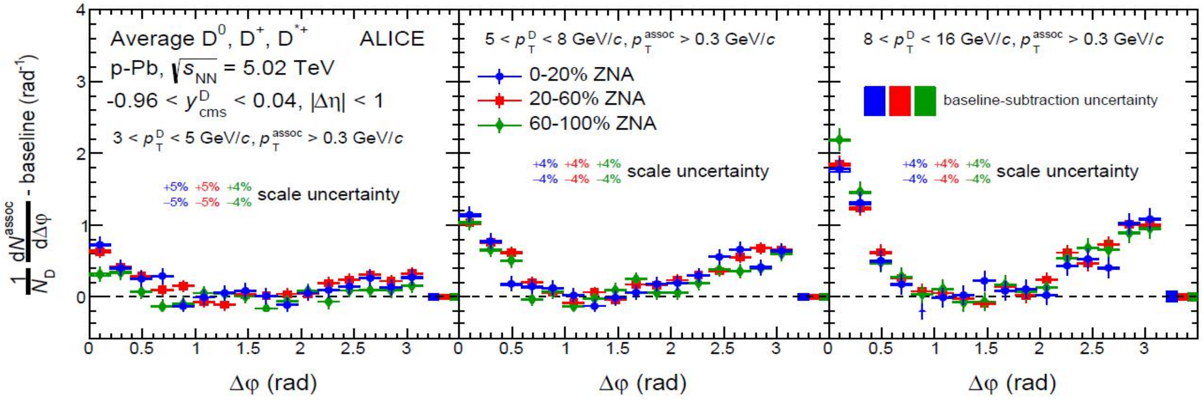
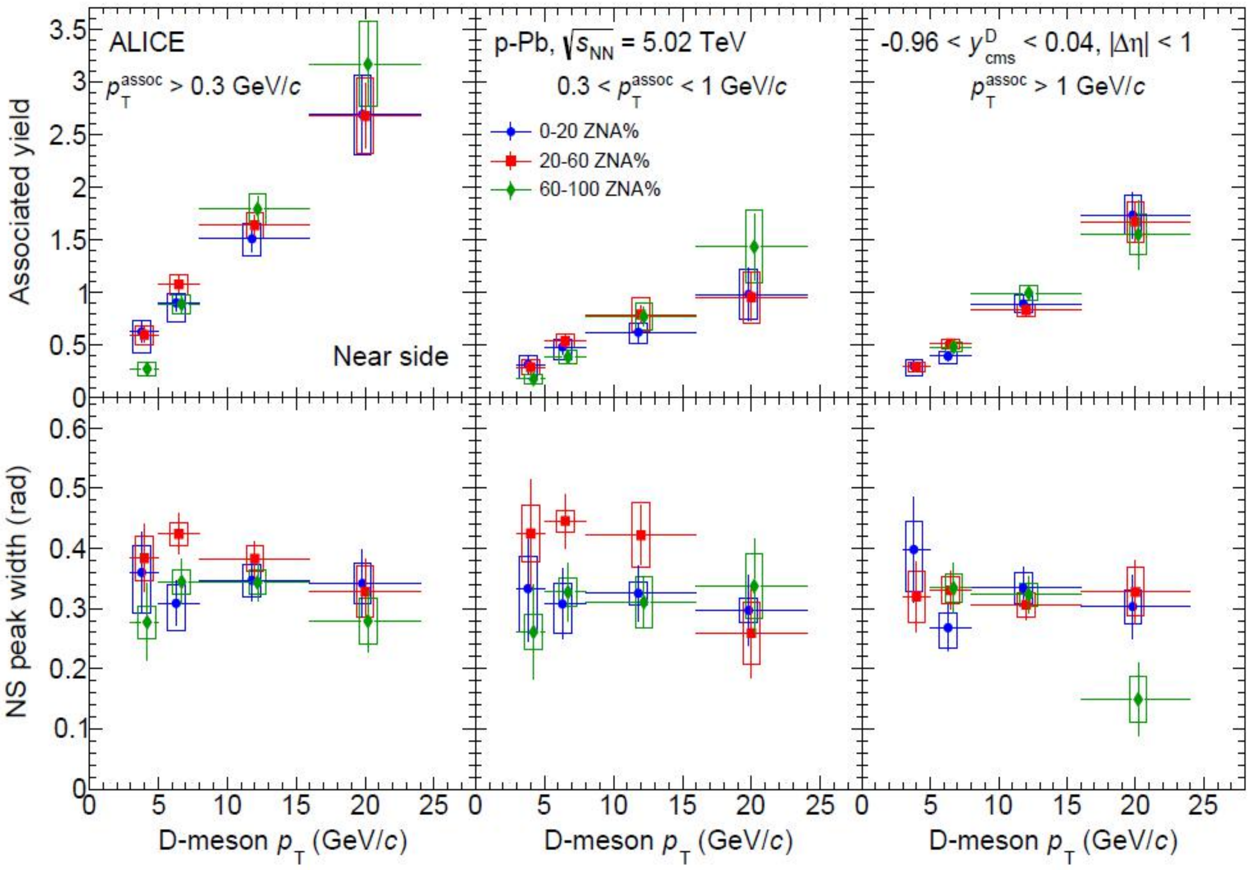
Backup

Function fitting (4C)



Results in p–Pb collisions as a function of the event centrality





No strong centrality dependence on the correlation peaks, which could have possibly been induced by nuclear-matter effects or multiplicity-dependent vacuum-QCD effects.